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Brief Report

Aging and Memory for Numerical Information: The Role of Specificity and Expertise in Associative Memory

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In order to examine the nature of associative memory deficits in old age, the present study examined how younger and older adults link numerical and object information to other items. The hypothesis was that there would be large age differences for numerical information caused by the arbitrariness and specificity of this type of information, but that this could be reduced by expertise. Participants studied sentences that contained numeric quantity, object, and location information (e.g., 26 cherries in the bowl); they were later cued with the location and had to recall the object and quantity. In general, there were significant age differences for quantity recall but negligible age differences for recall of related objects but not unrelated objects. However, a group of older retired accountants and bookkeepers showed exceptional memory for quantity information. The findings suggest that the associative deficit in old age is based on the linking of specific arbitrary information.

THE ability to remember numerical information is essential, given the variety of numerical information that we process every day. It is often important to bind numerical information with an appropriate context or item, such as remembering how many eggs are required for a recipe, remembering the street address of someone's house, or recalling the prices of various items so that one can later make an informed purchase. These situations involve remembering numerical information as well as binding this information to specific items or contexts, which can be considered a form of associative information.

Previous research suggests that older adults have a specific deficit in binding information to form associations (Chalfonte & Johnson, 1996), such as proper names and faces (e.g., James, 2006). Naveh-Benjamin (2000) has proposed an associative deficit hypothesis to explain older adults' memory impairments (e.g., Castel & Craik, 2003). However, relatively little research has examined age-related differences in the ability to remember numerical information that is bound to other items, and this represents an important avenue of research as number–word pairs can contain very little semantic information, relative to word pairs. When information does not contain any useful semantic information, older adults might display poor memory because it is difficult to incorporate and organize the incoming information with prior knowledge.

Hess (2005) has suggested that age-related changes in memory performance should be examined in terms of contextual factors, including the role of how prior knowledge and expertise can be used to enhance motivation and subsequent memory performance. Castel (2005) found that older adults were particularly good at remembering the price of grocery items that were of market value (e.g., milk $3.29), but, relative to younger adults, they had much greater difficulty remembering the price of arbitrary (and unrealistically) overpriced grocery items (e.g., bread $12.49). Thus, expertise helped older adults remember numerical information when prices were somewhat consistent with their prior knowledge. A similar approach has been outlined by Jenkins' (1979) tetrahedral model, in which memory performance is determined by interactions among participant characteristics, strategy use, materials, and the manner in which one assesses performance. The present study emphasizes these points by examining how memory for arbitrary associations is influenced by semantic relatedness and specificity of the materials, and how this interacts with age and expertise.

The present experiment examined how younger and older adults remember verbal and numerical information, and how this information is bound to form a complex unit of information. Participants studied phrases that consisted of a number (quantity information), an object, and its source location (item information). The object–location pairs were either mildly related (86 hotels in the city) or unrelated (58 nails in the bowl), whereas the numbers were always unrelated and arbitrary. I hypothesized that there would be small or negligible age differences for object recall in the related condition, but much larger age differences for number or quantity recall, because this represents more arbitrary and specific associative memory. I expected to find age differences for both types of information in the unrelated condition.

In order to examine whether age-related differences in memory for arbitrary and specific associative information are influenced by expertise in a relevant domain, a group of older, retired accountants and bookkeepers was also included in the study. Previous research on aging, expertise, and memory has shown that expertise can facilitate memory performance for domain-relevant information (see Krampe & Charness, 2006, for a review). This has been demonstrated in domains such as memory for chess (Charness, 1981), cooking information (Miller, 2003), aviation information (Morrow, Leirer, Altieri, & Fitzsimmons, 1994), spatial layouts (Hess & Slaughter, 1990), and music (Meinz & Salthouse, 1998), although in many cases expertise simply leads to similar benefits in performance for both younger and older adults (see Arbuckle, Cooney, Milne, & Melchior, 1994). I thought that the accountants and bookkeepers in the present study would benefit from their extensive prior experience with numbers, and display good memory for numerical information and the necessary association, relative to other older adults. This would suggest that the ability to remember item and associative information (and any age-related differences in associative memory performance) is dependent on the specificity of the materials used, and the manner in which the information is processed in light of prior knowledge and experience.

Methods

Participants

Forty-eight undergraduate students from the University of Toronto volunteered to participate for course credit: There were 33 women and 15 men in this group (age, $M = 21.5$, $SD = 3.3$; number of years of education, $M = 15.3$, $SD = 1.1$). Forty-eight healthy older adults also participated in the study and were paid $10: There were 34 women and 14 men in this group (age, $M = 71.3$, $SD = 5.3$; number of years of education, $M = 14.8$, $SD = 2.5$). In addition, a group of older adults who had some degree of professional experience working with numerical information (specifically, retired bookkeepers and accountants) was recruited by advertising in a local senior's newspaper. This group comprised 12 older adults: There were 7 women and 5 men (age, $M = 73.9$, $SD = 8.2$; number of years of education, $M = 15.3$, $SD = 1.9$). They reported more than 20 years of professional experience as bookkeepers or accountants (or financial assistants), and they were paid $10 for their participation.

Materials

The phrases consisted of a two-digit number, an object, and a location. The objects and locations were either related (hotels in a city) or unrelated (nails in a bowl). All numbers were randomly assigned and ranged from 10 to 99. The materials were developed by asking a group of subjects (who did not participate in the actual experiment) to provide common nouns that were either related to the location or plausible but completely unrelated. The phrases were constructed such that pairs were not exceptionally high associates, but they were similar in terms of word length and frequency (as determined by an independent judge).

Procedure

I randomly assigned younger and older participants to either the related or unrelated condition (with the exception of the older accountants or bookkeepers, who all participated in the unrelated condition). An experimenter told participants that they would be presented with 18 short phrases that consisted of a two-digit number, an object, and a location. The experimenter showed the participants each phrase on a computer screen for 10 seconds; the order was randomized for each participant. Immediately following the last phrase, the experimenter gave the participants a cued recall test in which the locations were presented one at a time. The experimenter instructed participants to verbally recall the number and object. The entire session took approximately 30 minutes.

Results

The results for correct cued recall of number and object information are shown in Figure 1. The recall of number information was only scored as correct if participants provided the exact number that was originally paired with the object and location. I conducted a 2 (age group: young or old nonexperts) × 2 (information type: number or object) × 2 (relatedness: related or unrelated) analysis of variance on recall performance for object and numbers. It revealed that young adults recalled significantly more information than older adults did, $F(1, 92) = 34.6$, $MSE = 15.5$, $\eta^2 = .27$, $p < .0001$; that object information was better recalled than numbers, $F(1, 92) = 432.4$, $MSE = 4.56$, $\eta^2 = .83$, $p < .0001$; and the recall was better for related pairs, $F(1, 92) = 26.3$, $MSE = 15.5$, $\eta^2 = .24$, $p < .0001$. Most critically, there was a significant three-way interaction: $F(1, 92) = 10.76$, $MSE = 4.56$, $\eta^2 = .11$, $p = .001$. Figure 1 shows that the interaction reflects that older adults recalled less than younger adults did when the information type was quite specific (numerical information), but that negligible age-related differences were evident for the recall of related information. The finding of minimal age-related differences for semantically related word pairings is consistent with the findings of previous research (Light, 1992; Naveh-Benjamin, 2000). However, when information was specific, arbitrarily linked and unrelated, age differences in memory performance were apparent.

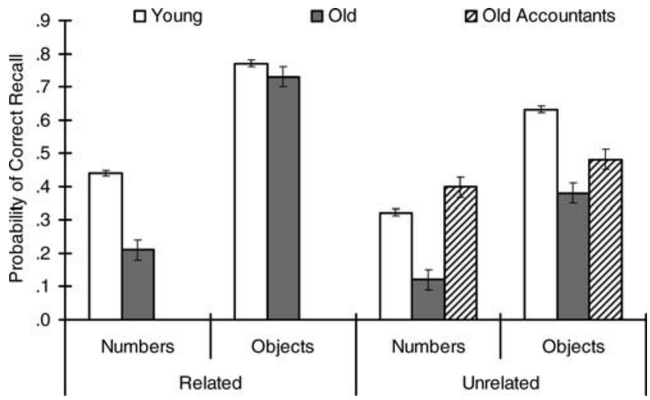

Figure 1. The probability of correct recall for numbers and objects in the related-object and unrelated-object conditions by younger adults, older adults, and older adults who were accountants and bookkeepers. Error bars represent standard error of the mean.

If expertise in a specific domain can influence the manner in which information is processed and later retained, it might be expected that the older accountant group would be particularly good at recalling numerical information, relative to the other groups and other types of information. The results displayed in Figure 1 suggest that this was indeed the case. This observation was confirmed by a 3 (group: younger adults, older adults, and older accountants) × 2 (information type) analysis of variance on the unrelated object data. There was a main effect of group, $F(2, 57) = 14.54$, $MSE = 15.01$, $\eta^2 = .34$, $p < .0001$, and information type, $F(1, 57) = 90.43$, $MSE = 4.58$, $\eta^2 = .61$, $p < .0001$, as well as a significant interaction, $F(2, 57) = 7.44$, $MSE = 4.58$, $\eta^2 = .21$, $p = .001$. From Figure 1, it appears that the older retired accountants displayed excellent memory for numerical information. Post hoc (Tukey's) tests confirmed that the older accountant group and younger group did not differ from one another ($p = .32$, power $= .28$), but that both groups displayed better numerical memory performance than did the older group

($p < .001$ in both cases). Post hoc tests for object recall showed that the younger adults differed from both the older accountants ($p < .05$) and the other older adults ($p < .001$), but that the two older groups did not differ from one another ($p = .29$, power = .31). Although it is possible that the older accountants differed from the older adult group on other measures of memory, this finding suggests that expertise influences associative memory in the domain of expertise (number recall), but it does not necessarily lead to better overall associative memory performance.

Discussion

The ability to remember specific arbitrary numerical information bound to other items appears to be impaired in older adults, but expertise can reduce this deficit in associative memory. The findings that older adults can remember specific numerical information (such as market value grocery prices; see Castel, 2005) and, in the present study, when one has a certain level of expertise that is specifically related to the materials (e.g., accountants and arbitrary numbers), suggest that memory for item and associative information should be investigated in terms of situational and participant variables (cf. Hess, 2005; Jenkins, 1979). Given that a younger accountant group was not included in the present study, it is not clear whether expertise can truly eliminate age differences; however, older accountants appeared to process numerical information in a way that led to better memory, possibly as a result of strategy use or accessible domain-relevant information (e.g., Bédard & Chi, 1993; Krampe & Charness, 2006). In terms of binding, because they already efficiently process the numerical information, older accountants may be able to direct more processing resources toward remembering associations.

One way to conceptualize the findings from the present study is in terms of a hierarchical organization of associative memory, in which access to various levels of "associative specificity" depends on the person's ability and various situational factors. Craik (2002) suggests that as to-be-remembered information becomes more specific, age-related differences in memory performance become more apparent—and this is especially true in that older adults have difficulty recalling proper names relative to occupation information (e.g., Rendell, Castel, & Craik, 2005). In the present context, the ability to remember general and more specific levels of associative information likely depends on the person's ability and can be influenced by factors such as motivation, specificity of the materials and context, and expertise (Castel, 2007). For example, in some situations one may need to encode specific information (e.g., your hotel room number is 1203, or flight number), whereas in other cases relying on a more general level of representation is sufficient (e.g., remembering that your flight leaves at approximately noon). Older adults may not allocate sufficient attention to specific numerical information that is low in semantic value, but in some cases (e.g., remembering grocery prices, or having experience with accounting), older adults can recruit necessary processes, leading to benefits in memory. Thus, the degree of specificity with which one examines the ability to bind information, the variety of materials that are employed, and the different strategies and prior knowledge utilized by younger and older adults are important factors that influence associative memory performance across the life span.

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